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ABSTRACT

This annual report describes the 1999 activities of Research Corporation, a foundation that supports research programs at colleges and universities in the United States and Canada. It focuses on three primarily undergraduate institutions, two private and one public, that are active producers of published research and students going into the sciences. These schools are: (1) Hendrix College, Conway, Arkansas; (2) California State University, Fullerton, California; and (3) Occidental College, Los Angeles, California. Interviews at these three colleges showed how their faculties have successfully integrated research into their science departments in spite of limited resources. At all three institutions, a change occurred from an almost exclusive emphasis on teaching to an emphasis on research with teaching. The report also presents information about other activities of Research Corporation through its various awards programs. Grants approved during fiscal year 1999 are listed by program and institution, and financial statements for the foundation are included. (SLD)

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Research Corporation Annual Report 1999

ED 448 664

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UNDERGRADUATE RESEARCH: THREE INSTITUTIONS' SUCCESS STORIES

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THE ROLE OF A FOUNDATION IS TO SERVE AS A CATALYST FOR CHANGE. Research Corporation, through our grants programs, our investments in science and technology, and through sharing the accumulated insights and experiences of our staff and consultants, continues to have an impact in the sciences far beyond the actual dollars spent in the support of basic research.

In 1999 the foundation's Department Development Program completed a successful partnership with Hendrix College that has resulted in new facilities, programmatic enhancements, and a major evolution in the college's programs in physics and chemistry. Working with the Murdock Charitable Trust, the foundation also initiated a new program with Western Washington University directed toward an expanded program in chemistry that will build upon existing strengths and develop new programs that integrate existing programs with those in biochemistry.

The successful casting of the second 8.4 meter mirror and initiation of the polishing phases coupled with completion of the building brings us closer to the anticipated "first-light" in 2003 for the Large Binocular Telescope (LBT). With the instrumentation that is being developed by our partners at the University of Arizona, Ohio State, Notre Dame, and in Germany and Italy, the LBT will open new frontiers in observational astronomy.

The resources being provided by the foundation to support research programs in colleges and universities in the United States and Canada continue to be important in launching the careers of young scientists and in strengthening the quality of educational and research experiences for faculty and students at all levels of the educational spectrum.

Board of Directors

The Research Corporation Board of Directors met twice during the year to approve the foundation's budget and the award recommendations of the Program Advisory Committee. The membership of the board remained constant during 1999.

The foundation is grateful for the exemplary service of its board members who share the foundation's objectives and who volunteer their time to attend board meetings and to serve on committees and special study groups.

Program Advisory Committee

This year saw the addition of two new members to the foundation's Program Advisory Committee. Joining the committee in 1999 were Donald R. Deardorff, Professor of Chemistry at Occidental College; and David A. Tirrell, Chair of the Division of Chemistry and Chemical Engineering, Ross McCollum-William H. Corcoran Professor and Professor of Chemistry at the California Institute of Technology.

Contributors

Other organizations contributing to Research Corporation's Partners In Science Program during the year included the M. J. Murdock Charitable Trust, and the Camille and Henry Dreyfus Foundation. As Research Corporation phases out its administration of the Partners In Science program, long-time cosponsor, the M.J. Murdock Charitable Trust, will assume its administration in the Pacific Northwest.

John P. Schaefer
President
Research Corporation

MOUNTING A VIGOROUS PROGRAM OF RESEARCH IN PHYSICS OR CHEMISTRY AT AN UNDERGRADUATE INSTITUTION CAN BE A FORMIDABLE UNDERTAKING. Favoring success are the enthusiastic support of faculty and administrators, laboratory space, instrumentation, start up funds, time to do research and, ultimately, success in attracting support from private foundations, government agencies, and even local industry.

How have research-active college and university faculty established and maintained excellence in their departments? Do they have advice for their colleagues at other undergraduate campuses? What are the experiences of faculty in physics and chemistry departments that are striving to initiate or strengthen a "research culture" — to make research not only an expectation for faculty and science majors, but the driving force behind science teaching?

Face-to-face interviews were conducted at three primarily undergraduate institutions, two private and one public, that are active producers of both published research and of students going into the sciences: Hendrix College in Conway, Arkansas; California State University, Fullerton, and Occidental College in northern Los Angeles.

Why these three? Their faculties have successfully instituted research and integrated it into science departments from small to large. All of the departments have limited resources. A change from an almost exclusive emphasis on teaching to an emphasis on research with teaching occurred at all three institutions.

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UNDERGRADUATE RESEARCH:
Three Institutions' Success Stories

Physical chemistry professor David Hales helps Hendrix students aquire the skills necessary to operate and interpret data from the department's nuclear magnetic resonance spectrometer.

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A Transition from a Regional to a National Reputation

Nestled alongside the Arkansas River 30 miles northwest of Little Rock, is the town of Conway, home of Hendrix College and its 1000-plus student body. Renowned as the undergraduate training ground for a significant fraction of the state's medical doctors, Hendrix's reputation was, until recent decades, almost exclusively regional—as symbolized by an outline of the state of Arkansas on its annual catalogs.

The campus, lined by attractive brick buildings, gorgeous flower beds and tree-shaded walks, bespeaks a comfortable atmosphere and a civility that Dean John Churchill traces to Hendrix's Southern Methodist heritage. Its settled appearance notwithstanding, however, the winds of change have been blowing across campus with two new buildings devoted to the natural sciences just completed, and a third completely remodeled.

As important as the buildings, however, is the inclusion of undergraduate research, especially in the natural sciences, as a major component of Hendrix pedagogy.

How did this modestly endowed ($150 million) liberal arts college, named for an obscure Methodist bishop, rise to a position of strength in the natural sciences, one that has faculty and students engaged in research, publishing regularly and attending national meetings in force? Indeed, with a tuition of $13,000 per year, and a growing reputation in the sciences, Hendrix is challenging more prestigious and wealthy institutions to the north.

How did this modestly endowed liberal arts college rise to a position of strength in the natural sciences?

Hendrix's rise in the sciences rests on a venerable tradition. Following the 1925 Scopes Monkey Trial in neighboring Tennessee, Arkansas voted by popular referendum in 1928 to forbid the teaching of evolution in the state's public schools, colleges and universities. The response of Hendrix President John Hugh Reynolds was to raise $300,000, half from the General Board of Education in New York, predecessor to the Rockefeller Foundation, and half from the Conway, Arkansas, municipal utility corporation, to provide a building in which science could be taught without political intervention. The outcome was Reynolds Hall, recently reconstructed and renovated, and still used for the teaching of science.

In the last few decades, what has been accomplished at Hendrix amounts to a culture change, a shift from an almost exclusive concentration on classroom teaching that discouraged research, to a situation in which research is not only expected and strongly supported, but is a requirement for tenure.

Although Hendrix was the beneficiary of a Research Corporation Department Development Award in 1993, the main effect of the award was to strengthen trends that had already been established and to hasten the refocusing of the physics and chemistry departments—to some extent the entire college—toward research as part of teaching.

Physics at Hendrix

Physics chair and senior department member Richard L. Rolleigh, whose memories extend back to 1963 when he was a Hendrix physics major, is well qualified to talk about departmental evolution. Even 40 years ago, Professor Rolleigh remembers, there was research interest on campus, but faculty and students went to *other* campuses during the summer to do it.

The teachers were good or even "outstanding" according to Rolleigh, but for professional activities that included research they were "beaten to death by lack of facilities and equipment. They finally quit demanding. I was young when I

returned as a faculty member and chair in 1974," he says, "and was willing to be assertive." As chair he decided to try to improve the department's equipment inventory, and tells of submitting an approved instrument award for matching funds and asking if the administration would match a second. The response was negative—"If you get another grant you'll have to return it because we won't match two," he was told.

Not discouraged, he spent his summers doing research at the University of Texas at Austin, where he had received his Ph.D. in theoretical particle physics in 1972, taking students with him whenever possible.

The problem, he recalls, was that the Hendrix administration of the time viewed these labors as having zero benefit and gave no credit for them. "In fact," he laughs, "it was actually suggested in one of my early evaluations that I was *too* interested in research. It was clear that they didn't like what I was doing and viewed research as taking time away from lesson plans. I didn't stop doing research," he concludes, "but I probably lost some of my enthusiasm."

There were encouraging developments by 1985. A NSF-College Science Instrumentation Program (CSIP) grant was approved for "Computer Interfacing of Laboratory Instrumentation." A second NSF-CSIP grant followed in 1987, and an NSF-Instrumentation and Laboratory Improvement (ILI) grant in 1992 further alleviated the instrumentation problem. The awards also raised administration awareness of physics' needs: the department's supplies budget was increased from $1,000 to $10,000 between 1984 and 1992. (In 1999 the department had an annual operating budget of $23,000 with capital items listed at $10,500.)

With increasing frequency, Hendrix physics graduates were being admitted to the better graduate programs; its students won NSF Graduate Fellowships in 1977, 1982 and 1990. The number of physics graduates grew to seven in 1987 and remained at that level until 1991, with roughly half attending graduate school, and many of the others opting for engineering. Unfortunately the faculty teaching load remained so high that research activity during the academic year in the late '80s and early '90s was very difficult.

A transition had begun that culminated with the presidency of Ann Die in 1992. "The dam broke," says Rolleigh. "It was made absolutely clear that the new administration supported undergraduate research." Summer research in physics at Hendrix was supported by Research Corporation project grants, an award under the Collaborative Arkansas Research Partnerships program, and by NSF-Research in Undergraduate Institutions (RUI) support in 1989–1992.

It was made absolutely clear that the new administration supported undergraduate research.

Professor Pradip Bandyopadhyay ("Bandy" to colleagues), a graduate of Jadavpur University in Calcutta and of Oklahoma State, who has received NSF-RUI support, takes up the story at his arrival in 1985, when he joined Rolleigh and Professor Robert Dunn. "The seed had been planted," he says. "I was expected to apply for grants and do research." Much progress had been made, but inadequate facilities and faculty teaching loads limited research opportunities.

A stimulus to further development was Research Corporation's Department Development Program to "expand excellence in research and teaching" at undergraduate chemistry and physics departments. This invitational program, which made a first award in 1991 to the University of Wisconsin-Eau Claire, was designed to fund development efforts at departments selected on the basis of faculty accomplishments, student productivity, foundation studies and outsider recommendations. Institutions hosted consultants who helped measure strengths and weaknesses, assist faculty and administration to develop a master program, and to monitor performance under it. Hendrix was invited to apply under the program, and completed a proposal in 1993 that was subsequently reviewed and approved.

The award facilitated the hiring of an additional faculty member and a laboratory manager for physics, and similar additions for the chemistry department. The

effect was to reduce teaching loads and provide time for faculty to do research and oversee labs. The normal teaching load in both physics and chemistry is currently set at three courses and three laboratories, a figure that includes the expectation of research and supervision of students. In addition to the academic year, faculty members typically work ten weeks during the summer in contact with student researchers.

The Research Corporation award was a challenge to the department as much as it was an aid to its development: not only was a firm commitment to research required by the conditions of the grant, but there were a number of objectives to be met; annual visits by consultants were conducted to monitor performance, and faculty and administration were advised of shortcomings.

"There were times the consultants had some pretty tough comments and specific suggestions for correcting deficiencies," says Hendrix President Ann Die. "The faculty, Dean Churchill, and I would meet, reaffirm our commitment to all the terms of the grant, and determine that we were not going to fail."

Instituting a Research Model: There's No Going Back

Making a change from a traditional to a research-driven curriculum is anything but easy. If you ask the Hendrix physics department how you go about doing it, you hear not only "commitment," but "passion," the word used by Pradip Bandyopadhyay.

"Does your faculty, or a least a majority want to get involved?" asks physics chair Rolleigh. "It's not productive to make teachers participate if they don't want to, but you must have research if you want a good shot at becoming outstanding. You've got to get the administration behind you." Like peer review, the discussions along the way can be healthy, he feels. "If we had gotten everything we asked for the first time, we wouldn't have had to plan as well as we have."

Ask yourself whether you really want to put your institution at a national level. There's no going back.

A change to a research model carries tremendous responsibility, says Pradip Bandyopadhyay. "It requires not only passion, but a constant dialog with the administration. To initiate change, one should start by exploring available grant programs and submitting applications. Finally, one has to show the funding agency that the department has the potential to achieve what it is aiming for. Ask yourself," he concludes, "whether you really want to put your institution at a national level. There's no going back."

One other element that helps make scientific investigation part of the faculty job description is a research champion. Fortunately for both physics and chemistry at Hendrix, such a person was found in Professor Tom Goodwin of the chemistry department.

Hendrix's Research Champion

"Goodwin came to Hendrix in the late 1970s with the vision to blend research and teaching and a passion to make it possible on this campus," wrote Dean John Churchill recently. "He led by example, conducting research with undergraduates under adverse conditions most charitably described as benign neglect."

Born in Arkansas and graduating from the University of Arkansas-Fayetteville with a Ph.D. in organic chemistry, Goodwin discovered after a postdoc at Rice, a stint with Conoco Chemicals and a period at Texas A&M as a lecturer and research associate, that his roots were in Arkansas. Although he enjoyed the stimulation of large universities, he put his doubts about small colleges aside when a job opened up at Hendrix. "Good teaching jobs in organic chemistry don't open up very often in a small state like this," he points out, "and I would have taken a *bad* teaching job to live here." Hendrix's reputation in the sciences and its physician alumni notwithstanding, the college didn't have a lot of history of externally funded research or publication in mainstream scientific literature. "Frankly," Goodwin says, "it had rarely been allowed or encouraged."

Coming to campus for an interview in 1978, he told the committee that he wanted to do research, needed to do it to be happy, and felt it was a vital part of teaching science. "I came at a good time," he says, "because the department, the dean and the president all said yes," but when it came to the question of what would be provided to make research possible, the answer was "not a whole lot." It was, indeed, a case of benign neglect. "Not much was known on campus in 1978 about research, about NSF, NIH, or any other kind of grants. But the college had gotten educational grants, the dean was a physicist, and my colleagues were supportive, so I decided I would try to overcome the obstacles. I was confident that I could come up with some good science—good ideas—and that's the first requirement.

"It was clear this was not going to be easy," he recalls. "You had to carry your own teaching load, get your own money for research and apply for instrumentation grants—a lot of hard work, luck and persistence. If you go into a liberal arts school that already has a research culture, someone has paved the ground for you; at a major university research is taken for granted." Goodwin tells about the NMR at Hendrix when he first arrived, old and slow at 30 MHz (the current state of the art at undergraduate institutions is 400 MHz). "I've only seen two that old," he jokes, "both in Arkansas—maybe the manufacturer had something against us. A proposal to NSF got us a 60 MHz NMR—an improvement."

You have to have good ideas; then you need to convince the funding agencies that you can do the work.

Comments Goodwin, "You have to have good ideas; then you need to convince the funding agencies that you can do the work." His first resolution: have research proposals submitted to funding agencies *before* he even arrived at Hendrix. He completed two applications, the dean signed them and both were funded. You can't get support by "sitting around and telling people why you can't do research," says Goodwin.

"You have to remember you're applying from a small school not necessarily familiar to the funding agency," he continues, "and people are going to say, 'this guy could never do this work at that place.' So preliminary results are very important to prove that you can do what you propose. Maybe you have to drive across town to get an NMR spectrum, or take your samples to Little Rock or go to Fayetteville to use their library, but you're producing results. My strategy was to tell the granting agency that we were not only doing research like that proposed, but just think how much *more* we could do if we had a better NMR at Hendrix."

As Professor Goodwin, interested in the synthesis of medicinally-active natural products, received funding, publications and additional grants followed, as did an increase in the number of chemistry faculty involved in research. He remained alert to new research: a recent example is a study of the secretions and estrous cycle of elephants in an Arkansas sanctuary—now the topics of papers and presentations by Goodwin and his students.

He found the publicity which resulted from his first investigations "a bit disconcerting, but good PR for the college. It helps the administration recruit students if you get a mention of the research on TV or the front page of the paper," he relates. "When you've had some success you can point out the many benefits to students and the college as a whole, and you can also make the point that, in order to continue, some teaching credit for research is necessary. In my case I went to the dean and said that if it is important to the college that we keep this research program going, some readjustment in teaching responsibilities will be necessary. We were able to work out within our department an equitable redistribution of responsibilities, and the dean approved it."

Warfield Teague, the most senior of the five-member chemistry department with over 30 years of service, and chairman of the science facilities planning committee responsible for the design and construction of Hendrix's new science buildings, traces the evolution of the department with the arrival of each new

member. A Ph.D. graduate in physical inorganic chemistry from Purdue, he had done research in laser spectroscopy at the Army Research Laboratory at Aberdeen Proving Ground. The two-and-a-half person department he joined in 1970 was not encouraged to do research during the academic year, however, and he was told it really had no place in an undergraduate curriculum.

Following Tom Goodwin's ground-breaking efforts to include research, the door opened wider with the 1983 arrival of current department chair Randy Kopper, a graduate of the University of Kansas interested in the structure and modification of ribonucleic acids. In the case of the two newest additions, who came on board in 1992 and 1994 respectively, David Hales who received his Ph.D. from the University of California, Berkeley, and Liz Gron, a Ph.D. graduate of the University of Wisconsin-Madison, research was a condition of employment, and is now a requirement for tenure (although what this means in practical terms is still being defined). "Our attitude has undergone a major reversal over 17 years," Kopper says. External funding and student and faculty availability heightens campus summer research, which often leads to trips to professional meetings with sessions for undergraduate student presentations such as the ACS, APS and NCUR.

An average of 12 majors per year were graduated by the department between 1984 and 1993, with one or two per year going to graduate school, and six to seven going to medical school. Graduating students numbered eight in 1995, rising to 17 in 1996, with increasing numbers going on to professional training, and most participating in undergraduate research.

One of the greatest strengths of Hendrix's chemistry department seems to be the fact that its members not only respect each other, but genuinely like each other and do what they can to advance each others career goals. When David Hales, recently tenured, came on board, start-up money was found for some equipment, and the others tried to shield his free time to give him time to write proposals and launch a research program (Hales and his students study reactions of molecules within gas-phase clusters using mass spectrometric and computational techniques.) Similar attention was given to Liz Gron, the newest member of the department, now up for tenure, who has high praise for the department's effort to help and protect her from too many different demands on her time during her early years.

Its members not only respect each other, but genuinely like each other and do what they can to advance each others career goals.

Asked if he envied the start-up funds extended to new faculty, chemistry chair Kopper points out that equipment is more expensive than it was when he joined the department, and that newcomers are under a lot more pressure to produce publishable results. He attributes the seeming lack of strife in the department to its small size and the complementary strengths of its members. "We operate by consensus, and even though we don't agree about everything, we have similar priorities," adds David Hales. "We can convince each other or be convinced."

Although there were other departments slated to get additional faculty members before physics and chemistry, the two science departments "jumped the queue," in Randy Kopper's terms, leading to feelings of jealousy in some parts of the campus. There was no queue-jumping for lab and classroom space, however; it had long been in need of remodeling and expansion.

"Setting Up" the President

"When I became president in 1992, the physics and chemistry faculty invited me over for coffee and donuts—I was there about 15 seconds when I realized what they were up to," psychologist Ann Die laughs. Faculty members acknowledge it was a setup: they wanted the new president to see for herself the desperate straits they were in.

"After that, I started my alumni talks by telling people about that invitation to

coffee," Die says. "I told them it had fallen my lot to build the science buildings that were designated by the former administration as the highest priorities back in the 1980s. I reminded audiences that 40 percent of our current graduates are in the sciences—about a third of them in biology, physics, chemistry, mathematics and computer science, the balance in psychology. That's a huge percentage, and we could not delay any longer." Hendrix, a strong producer of graduates going into the sciences and medicine in common with other select liberal arts colleges, was in danger of losing its competitive edge because of obsolete and inadequate facilities.

Consultants in physics and chemistry from around the country had assessed our potential, and because of that Research Corporation was offering a unique opportunity.

Under the circumstances, an invitation to apply for a Research Corporation Departmental Development Award looked like a golden opportunity, and President Die seized it. "I was able to say that consultants in physics and chemistry from around the country had assessed our potential, and because of that Research Corporation was offering a unique opportunity," she says. But how about jealousy among other parts of the campus—those which had been slated to get additional faculty before chemistry and physics, and had even more students?

I was able to use that grant to quiet a potential firestorm," Die says. "It was probably hardest on biology, for they had huge teaching loads and large class sizes. This has since been addressed with biology adding more faculty and benefiting from a just-completed building and new equipment. Indeed, since the grant, Hendrix has found resources to enlarge the faculty overall by about 30 percent; to assist many departments with remodeling and renewal. "Call it three-dimensional chess," President Die concludes. "All pieces move in synchrony or you wind up with protest and rebellion."

Another benefit is a change in pedagogy in a number of fields: the idea, inspired by undergraduate research in chemistry and physics, is that a research experience or independent study with a faculty mentor could be a valuable experience in other disciplines.

Ann Die has also been able to even the score for that 1992 invitation to coffee and donuts with the chemistry and physics departments. "When faculty complained about the work load," she says, "I reminded them that I didn't ask them to sign onto the Research Corporation grant and to undergraduate research. 'You had me go to your colleagues in the humanities and social sciences and tell them why we had to do this—now we've done it, and it's up to you,'" she told them.

"I sometimes used that grant to motivate, challenge and cajole," she says, but more often her role and that of Dean Churchill has been to reassure, to say "we're going to get though this together."

AT RESEARCH CORPORATION, THE DECISION TO INVEST in individual scientists through our Cottrell College Science Award program is made by evaluating the science, the scientists and their environment. To advance science, we believe that we need to invest in career development as much as in a specific research project. Except for those individuals at the extremes, these decisions are not easy. What about strong science from a driven chemist or physicist in weak or unsupportive institution? I believe that in these cases the record shows that Research Corporation has overwhelmingly made positive decisions to provide support, that we come down on the side of the motivated scientist.

But evaluating institutional environment is easier and can be done more quickly than assessing what drives a scientist. Motivation, while perhaps more important, is also more difficult to measure. Yet, the large majority of our clientele are beginning faculty, with no independent track record, and about whom we may know little. Surely, a publication record during one's apprenticeship in a doctoral program and as a postdoctoral associate is a guide, but no more than that, and academic pedigree does not reliably predict future performance. Neither measures motivation with any certainty. Thus, more often than not we are left to decide on research proposed by faculty about whom we would wish to know more. Institutional environment naturally looms larger and weighs more heavily in any decision to make an award. The wealth generated in this nation during the nineties has endowed institutions, including the primarily undergraduate institutions, with the resources to make very significant improvements to the environments in which their faculty teach and do research. This fact is not lost on us and raises institutional responsibility.

Faculty and administrators need to be keenly aware that support for scientific research is based on the interplay of factors beyond the strength of the proposed science. At an undergraduate institution, the motivation to scholarship and the environment in which that scholarship is pursued, are the keys, crucial keys, necessary for the development of career-long teacher-mentors-researchers. These faculty advance science, enhance institutional excellence, and provide the research-rich programs that our undergraduate students need and want. It is in these careers that Research Corporation looks to invest.

—Ray Kellman, Senior Associate, Research Corporation

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Cal State Fullerton biochemistry majors Johnny Croy and Jennifer Padilla in the lab of Christina A. Goode, professor of chemistry and biochemistry.

Good Chemistry at California State University, Fullerton

Building an outstanding, research-oriented chemistry and biochemistry department at a public undergraduate institution with limited funds for start-ups and instrumentation, subject to state-wide salary scales, and attended by students often indifferently prepared and motivated, is an achievement to be celebrated. The Department of Chemistry and Biochemistry was founded in 1963—three years after the Fullerton campus took root in a former orange grove, and six years after its founding—and has prospered in the competitive Los Angeles environment, even through severe state funding droughts.

How it started is told by professor and former chemistry chair Bruce H. Weber, a 30-year veteran of the department who was one of nine new faculty hired in the late 1960s and early 1970s, most of them straight from postdocs at research universities. Professor Weber (he holds a Ph.D. from the UC, San Diego and did a postdoc at UCLA) and his new colleagues decided to do something about what they saw as a generally low level of expectations for the sciences at Cal State campuses, Fullerton included. "We wanted better things for ourselves and our students," Weber relates, "and decided to apply higher standards to ourselves." As a first step, they wrote new personnel requirements for the department.

Qualifying for tenure took just four years when Weber joined the department in 1970. Among the scanty requirements were one publication and the submission of a grant application. Current rules mandate seven years with the department, at least two major publications and two extramural grants. More pertinently, however, tenure candidates must have done extensive research work with Cal State Fullerton's students.

"There was a price to be paid for higher standards," Weber says. Among the casualties were faculty, hired when expectations were lower, who had not been able to make the grade to full professor, and some former faculty who were good researchers, but didn't want to spend time teaching.

Vital in building up chemistry were creative department chairs who helped get equipment, managed to arrange time for research, and somehow found money to send faculty members to meetings. Weber smiles as he talks about another problem overcome by the department. The state legislature's policy in the early 1970s, in keeping with the original California master plan for higher education, was that not being a research institution, Fullerton didn't require faculty research laboratories. "The chairman and vice president solved this one with semantics," Weber laughs. "Since 'teacher prep rooms' were permitted, they were added to the allotted space for graduate student research and teaching labs and became, in fact, our research laboratories."

Vital in building up chemistry were department chairs who helped get equipment, managed to arrange time for research, and somehow found money to send faculty members to meetings.

Administration support and understanding deans were also counted on to help round up funding. A big boost to the department was the addition of some outstanding teacher-scientists, normally beyond the recruiting reach of the Fullerton chemistry department, who relocated to Los Angeles area for personal or family reasons, and took faculty posts.

With higher standards for tenure came a departmental commitment to lighten the load on junior faculty and to support their research so they could gather data, apply for grants "and prove," to use Weber's words "that they could work here." A policy of matching any extra time provided by release time from a grant is in effect, but with the proviso that junior faculty members must teach at least one course a semester to monitor their growth as teachers. Generally, established, research-active faculty average two courses per semester at Fullerton.

One NSF grant to a faculty member in 1970 was followed by a flurry of others as the department became more research-oriented. "Momentum picks up," comments Weber. "Eventually it's not just people going to meetings to present data—it's people giving invited presentations at symposia here and abroad, writing book chapters and the like. That becomes the norm as a research culture is firmly rooted, and you bring each new member of the department into it."

One NSF grant to a faculty member in 1970 was followed by a flurry of others as the department became more research-oriented.

In the 1980s, Cal State Fullerton gained increasing visibility as a place where chemistry was being done. From 1985 to 1988, the department produced an average of 25 B.A. or B.S. graduates per year, and five degree recipients in its master's program. Partly because majors gain practical experience through summer research, a high percentage of those not pursuing graduate degrees found chemistry-related employment. Because of its productivity and minority enrollment Fullerton became eligible in 1990 to be included in NIH minority programs.

Production of chemistry graduates continued to increase in the 1990s, averaging 29 per year from 1993 to 1996, with 100 percent participation in research; 32 percent entered graduate school in chemistry. In 1999 B.S. and B.A. graduates in chemistry and biochemistry totaled 37, with seven going to graduate school.

Another sign of the success of science at Fullerton: a new $26 million science laboratory center completed in 1994. The building was needed as current figures attest: Cal State Fullerton's department of chemistry and biochemistry had a total course enrollment of 1,621 in the spring of 1999, including about 300 majors. Biochemistry accounted for about 180 and chemistry for 120; another 88 were graduate students.

Equipment Comes with Building

The limited ability of the Fullerton chemistry department and its administration to provide start-up resources for new faculty or to match large grants for instrumentation makes its success all the more impressive. "Fortunately, in California, you get equipment money when you get a building," says physicist Kolf O. Jayaweera, dean of the College of Natural Sciences and Math. "With our new Science Laboratory Center in 1994 we got $3.2 million to buy microscopes, centrifuges, everything for the labs." The dean managed to leverage the funds to best advantage by withholding $500,000 and challenging the faculty to apply for grants to match it. Success in that endeavor increased the $3.2 million to $4 million.

Dean Jayaweera wishes that a matching fund for start-ups could be established; "if a faculty member could get some money, we could match it," he says. 'Back in 1970 you could get something going for $5,000," adds former chairman Weber, "but today it takes at least $50,000 to get a lab going." At present, start-up funds for newcomers have to come from the department's budget.

Faculty member Christopher R. Meyer, who arrived in 1994 and whose professional interests include gene cloning and sequencing, believes the days of real budgetary malaise were the early '90s, "before I got here. Still," he points out, "the department's operating budget is lower now than it was in 1989. Prices are not lower."

Another problem for chemistry at Cal State Fullerton is falling enrollment, compounded by the fact that state funding is based on a head count of students. This provokes a critical comment from Chris Meyer—"We're training students in biotechnology and other economically vital fields," he says emphatically. "They clone genes, publish papers just like they do in Ph.D.-granting institutions, but because we have only 18 people in the biotechnology lab and 300 students in sociology, we have to scrape around for funds for the course." "Not only do we have a problem with numbers of students, but with their quality," adds Gregory M. Williams, a UCLA graduate who researches the applications of transition met-

als to organic synthesis. "We find a constant erosion of the academic skills and motivation of the students we encounter."

Dean Jayaweera believes that falling enrollment is due, in part, to the good economy and a plentiful supply of well-paying jobs. "Even though California's economy is driven by science, enrollment drops," he says "because youngsters think they can make as much money without going to college." Another reason for fewer students, he feels, is that the medical profession has lost some of its glamour, reducing the number of premeds taking chemistry and physics. One route of attack planned by Fullerton is to offer programs that will lead to alternate careers for science students such as the chemistry-business major that has been successful at the University of Wisconsin-Eau Claire.

Kolf Jayaweera and his faculty members interviewed for this report are justifiably proud of what has been achieved by Fullerton's undergraduate research program. "The legislators are always asking about how we spend money," Dean Jayaweera points out. "About three years ago we took a group of students and their faculty mentors to the state capital in Sacramento for a poster session so the students could show the legislators their research; the elected representatives listened—we're not sure if they understood or remembered at budget time, but they couldn't have missed the students' enthusiasm." Since then, the Sacramento poster session has become an annual, campus-wide event.

Rebuilding Undergraduate Science—Fullerton's Perspective

What advice would Fullerton faculty give those seeking to rebuild other undergraduate science departments? Younger members tend to stress adequate resources for research, and recognition for success. "If people aren't producing, get 'em out," said one member. "Be aware that there's an inherently higher price to doing science," said another. "If you want to have a top-quality program in chemistry, you have to be willing to pay for it."

Older members of the department tend to talk about hard work and sacrifice. "We have senior members willing to take a heavier teaching load for the sake of younger faculty," former chair Bruce Weber points out. "They also take more of the brunt of the committee work, more of the curriculum innovation, of covering classes to help younger faculty."

"When I look at departments at other institutions that aren't successful," Weber continues, "it appears to be because they didn't build a research culture. When you talk to the faculty you may find that, with the exception of one or two people, there's not the willingness to make the extra effort, to take the risk of adopting higher standards. Cultures are very hard to change from the outside: you've got to have leadership from within, a chair who realizes what needs to be done, and faculty who want it to be done. Without them it's almost impossible to change." He mentions other problems that are more or less endemic to state institutions: institutional barriers to getting the necessary resources and space to do research.

Cultures are very hard to change from the outside: you've got to have leadership from within.

Students are the ultimate justification for Cal State Fullerton's successful efforts to overcome these barriers. For these students, many of whom come from minority backgrounds and are the first in their families to attend college, the school can be the opportunity of a lifetime.

An Occidental student monitors an experiment with assistance from chemistry professor Tetsuo Otsuki.

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Chemistry in the Forefront of Occidental's Research Tradition

Occidental College, which owes its origins to the Presbyterian Church, shares Hendrix's legacy as a church-related institution, but unlike it, has a research tradition in chemistry that stretches back many years. Founded in 1887 in what was then a remote area of Los Angeles, Occidental originally taught Latin, Greek and mathematics. Dissolving its ties to the Presbyterians in 1910, the college moved to its hilly, wooded campus in the northern Los Angeles community of Eagle Rock a few years later.

Occidental boasts 150 faculty and 1600 students, 28 percent of whom graduate in the sciences. The college has formally committed itself to research as a part of education. "Faculty members involve students in cutting-edge discoveries and inquiries that challenge premises and axioms of many of the common views held in fields ranging from American Studies to Zoology," reads a mission statement.

Occidental's interest in research-driven pedagogy dates at least to the 1960s. A formative role was played by Richard C. Gilman, former academic dean at science-strong Carleton College who became president in 1965. Gilman promised key faculty that he would raise money for facilities and equipment if they would involve students in undergraduate research.

Frank P. DeHaan, who had his research origins as an undergraduate at Calvin College in Michigan, became the chemistry department's research champion, helping advance college efforts by maintaining an active research program and recruiting new faculty excited about doing science. "Everyone hired for chemistry in the past 25 years has assumed they were going to do research," says Dean David L. Axeen, a historian who is now vice president for academic affairs.

"We had some research-active people in the '60s, and the '70s, but it really started taking hold in the 1980s," Chris L. Craney, professor of chemistry and director of the undergraduate research center (which oversees a several programs for student projects), remembers. Craney, a graduate of Washington State University interested in biophysical chemistry, has seen an explosion in research activity since his arrival in 1982.

A good facility was already in place—Norris Hall of Chemistry which underwent a major remodeling in 1991. Norris has faculty offices adjacent to student research labs so professors can keep both an eye on, and their doors open for, students. Frequent grant applications and Oxy's unfailing policy of providing matching funds has given the department a good complement of instruments including two high-field NMRs. "The dean likes the idea of spending 50 cents on the dollar for equipment," said one faculty member.

Frequent grant applications and Oxy's unfailing policy of providing matching funds has given the department a good complement of instruments.

On the negative side in recent years, recurrent budgetary problems have made some economies necessary including case-by-case justification for large maintenance items. Everyone agrees that things do get fixed, but it takes more time and effort. "We have had to go hat in hand for major repairs," says one faculty member. Hopes are high that President Theodore R. Mitchell, an educator and historian who took over in 1999 will address this problem and others as part of a five-year "get-well" program.

Collegiality Overcomes Potential Problems

With a high esprit de corps, good facilities and success in obtaining grant support, research productivity and students going on to graduate training have been at high levels. This has been despite budgetary stringency, a just average salary

scale, and what was sometimes perceived as indifference to chemistry by the former administration. With 11 faculty members, the department turns out up to 20 chemistry or biochemistry graduates (B.A. or B.S.) a year, currently with about half going to graduate school. The Occidental campus really bustles with research activities after the spring semester—about 40 students and eight faculty members in chemistry alone.

We meet once a week, write grant proposals together, and share a common vision for the department.

Donald R. Deardorff, who joined Occidental in 1981, puts a lot of credit for the department's performance on its collegiality. "We meet once a week, write grant proposals together, and share a common vision for the department that includes research as a necessary form of teaching," he says. The members of the department not only work well together, but like and support each other.

A graduate of California Poly and the University of Arizona, Dr. Deardorff's research interests include the synthesis of biologically active molecules and the development of new methods for such syntheses. He classifies himself as a follower rather than a leader, although he has served as department chair. That job is not necessarily cherished in this close-knit setting—"everyone hates it. It literally drains your will to live," he says. Despite the fact that there has been some talk of making it a permanent assignment, Professor Phoebe Dea has agreed to accept it, although not forever. "They'll get tired of me after three years," she says.

A graduate of UCLA and Caltech and a 1993 addition to the department, Dea specializes in physical and analytical methods for determining molecular interactions of biological interest. She finds the chemistry department "very much like a family. We have 'interesting' meetings sometimes. We talk until we reach a consensus—there are no secret ballots. We fight, but when it's over, everything's fine, and we're together again."

It's considerations such as these, removed from monetary factors, plus a love of teaching and research, that keep faculty members at Oxy. "We'd like to do better by our teachers and researchers," observes Dean Axeen. "Research should be a factor in rewards," he believes, "because working with undergraduates slows things down and makes resumés a page or two shorter, but for us, of optimum length." He also points out that salaries at Occidental are level with peer colleges, but that most of Oxy's peers are in rural areas.

Closely related to the question of productivity are teaching and mentoring loads. A five-course load is normal at Oxy, with those involved in research getting a half-course credit. Added to teaching is research supervision (as many as 55 students in the chemistry department) and special projects and committees, for which additional adjustments may be made.

A key to the success of Occidental's science departments, in addition to collegiality, is faculty willingness to nurture and make sacrifices for newcomers. Two recent additions, Eileen Spain in chemistry and Mingming Wu of the physics department agree that their respective departments have been supportive.

Spain, one of only 20 scientists to receive a 1997 Presidential Early Career Award through the NSF Chemistry Division and the only one at a liberal arts college that year, gives Oxy credit for a "terrific" start-up package of $64,000 which enabled her to get a full matching grant of $32,000 from her NSF postdoctoral fellowship, something, she says, "senior members of the department did not benefit from [when they were first hired]."

Physics Joins the Research Culture

Undergraduate research in physics dates from the 1980s at Occidental, and awaited a change in administrations and the retirement of faculty members focused on a traditional curriculum. Another inhibitory factor: a graceful old physics building, Fowler Hall, with no laboratory space, loading dock or elevators, and seismically

unsafe. For the present, physics faculty must borrow lab space from the chemistry and biology departments until a new building, to be shared with geology and environmental science, can be completed.

The transition to a research-driven physics department was facilitated by a total turnover of faculty beginning about 15 years ago; "We basically rehired the entire department," says Dean Axeen, "and we specified that research should be required of physics faculty members at a liberal arts college." Retirements were also part of a similar restructuring in geology.

The collegiality among the five members of Oxy's physics department, supplemented by two part-timers, is enhanced by their being roughly contemporary in age and in length of service. The lack of serious disagreement in the department astonishes physics chair George Schmiedeshoff, who notes that he's the department's elder at 45, and that only one physics professor has been there longer.

We're here because we really like to teach, and we're judged as both teachers and scientists.

"I kept expecting some old white-haired guy to come in and say 'you kids get out of here and leave this to us,'" Schmiedeshoff laughs. "But the old guy never came in, and we put together a good, exciting curriculum, tried it out for a couple of years, and just finished tweaking it." A graduate of the University of Massachusetts at Amherst, he is interested in experimental condensed matter physics, good grist for undergraduate research. "Friends at MIT and Caltech are horrified by my five-course load," he observes, but "we're here because we really like to teach, and we're judged as both teachers and scientists."

For their start-up funding, the college gets high praise from Dan Snowden-Ifft, at Oxy for just three years. Interested in experimental cosmology, he was delighted when the college agreed to explore the possibility of building an underground research lab for his research on dark matter. This involves observing weakly interacting massive particles (WIMPs). "That lab's a $150,000 piece of hardware," he proudly explains.

Occidental also provided matching funds for his $300,000 NSF grant that includes a position for a teaching postdoc who could gain experience in doing high-quality teaching and research at the same time at a small college. "This could have been a sticky issue," says Snowden-Ifft, "because the teaching has to be up to Oxy's standards, but there's been nothing but full support."

Physics, like chemistry, is a hotbed of summer research activities, and up until this year, physics majors were required to do a research project in order to graduate. "They've worked out well in most respects, with students starting out feeling intimidated, but rising to the challenge," physics chair Schmiedeshoff observes. "Unfortunately, there were cases each year in which students had to choose between finishing their research or passing their other classes, so it was decided to make projects an option that everyone is encouraged to choose, and one required for honors."

Creating Successful Science Departments

Over the past decade, the college's chemistry and biochemistry graduates alone have captured three Rhodes Scholarships, five NSF graduate fellowships, 15 Goldwater Fellowships and numerous other awards. More than 85 in the past decade have entered Ph.D. programs in chemistry, biochemistry and the biological sciences, and 135 have enrolled in medical schools. The number of physics majors graduated by the department averaged eight per year for 1992–1995. There were eight in 1998, but only four in 1999. About half of the physics graduates go to professional school.

What advice can faculty and administrators give those interested in replicating Occidental's successes?

The way Chris Craney puts it is "good departments in strong institutions

around the country all have a sense of community, a shared sense of direction." The challenge? To get people to be part of a team effort even though they're of different ages and at different places in their careers.

"The things that work when you're fresh out of graduate school are not the same as those that work for those who have cleared tenure barriers, and the motivations are different," he continues. "Acceptance is the motivation for tenure, and money is the motivation for promotion to full professor, but these are not necessarily the motivations that will get older people to try new things. Putting ideas out there is a real risk," Craney says.

"Everyone has to be in agreement, undergraduate research has to be something everyone believes in," says chemistry veteran Don Deardorff. "Frank DeHaan got us moving, others were brought in, and once there was a critical mass, older faculty got back into research. It takes a strong leader and a critical mass. The research has to be meaningful; students know the difference between it and reinventing the wheel. You need projects that will challenge them and make them realize the significance of the work."

"Money helps," comments Dan Snowden-Ifft in physics. "The willingness of the administration to back research, the collegiality of the department, the willingness of my colleagues to help out. These take years to develop."

Dean David Axeen agrees that developing an undergraduate research program takes steadiness of purpose and a conscious decision. "It's got to be a priority in funding, in evaluation and in the reward structure. Establishing a program may mean cultural conflict with established people who are operating differently," he concedes, "but the good news is that there is external support for undergraduate research, and enlightened people who realize this is a resource for generating future scientists."

Developing an undergraduate research program takes steadiness of purpose and a conscious decision.

Literally all majors and faculty in physics and chemistry are working on grant-supported projects, or such support is not far off," Dean Axeen says. Student research has become the model for the entire college, and has spread across other disciplines including the humanities in what Axeen terms a "signature program. This model, which began in chemistry and physics," he points out, "is now the model for the whole campus."

Conclusion

Successful science departments resemble an extended family more than any other social structure. Serious problems with the administration or between faculty members appear to be rare in these dedicated, hard-working families. Efforts are made to nourish and advance the careers of younger members and to help them get tenure. Illnesses, personal problems, sabbaticals and other absences are accommodated. Department members lend a hand when there are grants to apply for, classes to cover, or instruments to be coaxed into working order. "We never vote on anything," was a typical remark. "We just talk it through."

Conversations with the faculty members of these undergraduate science departments leaves one with a feeling of admiration for their success in accomplishing so much, often with so little, in advancing science and in training a new generation of professionals. It is, indeed, a question of passion, of dedication, that transcends salaries, benefits, institutional endowments and budgetary resources.

—W. Stevenson Bacon

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THE ENVIRONMENT FOR RESEARCH

Business enterprises have understood for some time the importance of the environment in which their employees work. So also have many academic institutions. When policies and programs that foster community and collegiality are in place, faculty can work together to achieve institutional goals. When these same institutions support professional development, faculty prosper and students taste of the wellsprings of knowledge. If research is a visible component of the enterprise, the institution benefits from the enlivened interaction between faculty and students, and society benefits from student career development and the advance of knowledge.

Research Corporation began its Department Development Award program during the 1990s to enhance the environment for research at selected undergraduate institutions. The program does not have specific guidelines or even a published description. Interest is initiated by Research Corporation rather than from the department or institution, based on foundation knowledge and understanding of the institution and its environment. Focus is given to the departments of chemistry, physics, and astronomy. Each institution selected to receive an award offered a unique challenge and opportunity. Four institutions received Department Development Awards in the 1990s: the University of Wisconsin at Eau Claire (chemistry), Lawrence University (physics), Hendrix College (chemistry and physics), and Bowdoin College (chemistry). A preliminary award was recently received by Western Washington University to conduct a self-study and prepare a proposal leading to a Department Development Award.

The requirements for the institution and its faculty are substantial in time, commitment and resources. Research Corporation catalyzes enhancement of the environment for research; the institution provides the feedstock. The formal lifetime of the award is five or more years with annual reports and on-site evaluations by experienced consultants. We recognize that, like student evaluations, the initial outcome may be different from that achieved in the long term. We are interested in both but hope that our efforts profoundly influence the long-term development of the departments as centers of excellence.

Grants approved during fiscal year 1999 listed by program and institution appear on pages 23–30 following the program review on the next page.

We hope you will see them, as we do, as worthwhile investments in the potentially innovative individuals and the institutions that they represent.

Michael P. Doyle
Vice President
Research Corporation

1999 PROGRAM REVIEW

Foundation awards approved in 1999 for research and research enhanced teaching to faculty in the physical sciences totaled $8,550,196 allowing for discretionary awards, recisions, and refunds. This total reflects an increase of over $3 million from 1998 approvals. For the programs listed, 200 new awards were funded in 1999.

Cottrell College Science Awards

The foundation's largest program featuring two cycles of awards each year, the Cottrell College Science Awards granted $2,612,770 to support faculty in chemistry, physics, and astronomy at primarily undergraduate institutions. The program, which encourages student research involvement, funded 79 out of 239 faculty applicants. This year's average award amount was $33,073.

Cottrell Scholars Awards

Out of 91 applications submitted, 18 Cottrell Scholars awards were made to university faculty to support excellence in both research and teaching in chemistry, physics and astronomy at Ph.D.-granting institutions. Each award of $50,000 can be used largely at the discretion of the scholar.

Research Innovation Awards

Forty-six Research Innovation Awards were granted out of 143 applications received, with 31 awards going to chemists. Made in amounts up to $35,000, the awards assist beginning faculty in Ph.D.-granting departments of chemistry, physics, and astronomy, and this year totaled $1,591,152.

Research Opportunity Awards

Research Opportunity Awards help midcareer faculty at Ph.D.-granting institutions to explore new areas of experimental research. Out of 16 candidates that were nominated by their department chairs for awards, 13 proposals were invited and 8 were funded for a total of $182,849.

General Awards

The foundation's General Awards support projects that enhance research or strengthen the infrastructure of science, but that fall outside of other program guidelines. Two awards totaling $85,000 were made in 1999.

Efforts were begun on a study of the role of research in the natural sciences at undergraduate institutions, sponsored jointly with four foundations.

Partners In Science Awards

In its final year, the Partners In Science program sponsored 82 active partnerships. Thirty-five new awards of $14,000 each were approved along with 12 supplemental awards that totaled $31,093. Cosponsors in 1999 were the M. J. Murdock Charitable Trust, and the Camille and Henry Dreyfus Foundation. The program provided stipends for high school teachers to participate in research at local colleges and universities over two summers. In 2000, funding and administration of the Partners program in the northwestern states will be assumed by the M.J. Murdock Charitable Trust. Research Corporation will continue to administer active awards and portions of the Supplemental program until 2003.

AWARDS APPROVED

January 1, 1999 to December 31, 1999

COTTRELL COLLEGE SCIENCE AWARDS

Bates College

Paula Jean Schlax: Relationships between rpoS mRNA structure and stability and osmotic regulation of translational initiation—$39,150

Brock University

James McNulty: Synthesis of pancratistatin and analogs: Structure based anticancer drug design—$35,107

California Polytechnic State University, San Luis Obispo

Derek E. Gragson: Probing the mechanisms of polyelectrolyte adsorption at solid/liquid and liquid/liquid interfaces with second harmonic generation—$31,500

John P. Sharpe: Experimental study of large two-dimensional arrays of coupled stochastic resonators—$37,685

California State University, Fullerton

Christopher R. Meyer: Structure/function studies of diverse bacterial ADPGlucose pyrophosphorylases—$34,178

California State University, Long Beach

Douglas D. McAbee: Structure-function analysis of the rat hepatic lectin 1-binding domain of lactoferrin—$40,268

California State University, Los Angeles

Matthias Selke: Oxygen activation by dinuclear complexes: Using singlet oxygen as a mechanistic tool—$32,499

California State University, Sacramento

Linda M. Roberts: Investigation of a conformational switch: Characterization of the amino-terminus of human apolipoprotein A-I —$33,417

Calvin College

Deborah B. Haarsma: Cosmological parameters through gravitational lens time delays—$33,352

Lawrence A. Molnar: Mapping and modeling radio emission from Saturn's rings—$30,719

Kumar Sinniah: Investigating intermolecular forces between complementary single stranded DNA molecules: A chemical force microscopy study—$40,000

Central Michigan University

Koblar Alan Jackson: First-principles studies of the Raman and Mössbauer spectra of GeS_2—$26,924

Colby College

Dasan M. Thamattoor: New approaches to the investigation of hydroxycarbenes—$35,105

College of William and Mary

Carey K. Bagdassarian: Enzymatic conformational fluctuations along the reaction coordinate—a molecular dynamics simulation of cytidine deaminase—$26,849

College of Wooster

Judith C. Amburgey: Synthesis and characterization of cyclohexyl phosphoserine compounds as phospholipid analogs—$31,500

Colorado College

Nathaniel P. Longley: Neutrino mass measurement with a "long baseline" detector: Colorado College initiatives—$31,000

Connecticut College

Stanton Ching: Nonaqueous sol-gel routes to microporous manganese oxides—$29,880

Marc Zimmer: Modeling the active site of green fluorescent proteins—$27,305

Denison University

Steven D. Doty: A study of the structures of star-forming regions: A new 3-D radiative transfer simulation and its application to astrophysical data—$34,000

Dickinson College

Amy E. Witter: Electrochemical investigations of polysaccharide-metal interactions in aqueous systems—$35,755

Gustavus Adolphus College

Gretchen E. Hofmeister: Asymmetric partial-helical Lewis acid complexes and their applications in chiral recognition and stereoselective reaction chemistry—$29,670

Harvey Mudd College

Thomas D. Donnelly: The ultrafast dynamics of nonequilibrium electron distributions in gold—$43,000

Hendrix College

Liz U. Gron: Tailoring palladium-catalyzed reactions for use in high temperature water—$35,905

Hope College

Peter L. Gonthier: Relativistic Compton scattering in neutron star magnetospheres—$30,347

Illinois State University

Richard W. Nagorski: Carbinolamides: Structure/reactivity relationships in an aqueous environment—$32,250

James Madison University

William Christopher Hughes: Electrochemical reactions involving wide band gap III-V nitride semiconductors—$36,702

John Carroll University

Catherine Miller: Determination of isotopic exchange in the copper isotopomers of laccase using ICP mass spectrometry—$22,500

Kenyon College

Elizabeth A. Ottinger: Design of peptides that inhibit the activity of protein tyrosine phosphatase SHP-2—$33,874

Lake Forest College

Jason A. Cody: Molecules to solids and back again: Solventothermal synthesis of new rhenium thiophosphates—$33,029

Longwood College

James D. Burgess: Binding rates of platinum based anticancer drugs to surface immobilized DNA—$31,220

Loyola College in Maryland

Brian K. Barr: Kinetics of the interaction of *Acidothermus cellulolyticus* cellulase E1 with fluorescent glycosides—$40,184

Marquette University

Suchismita Guha: Molecular imaging of conjugated molecules by Raman microscopy—$27,198

Francisco Lamelas: Structural evolution during solution-based heteroepitaxial growth—$14,000

Middle Tennessee State University

William M. Robertson: Applications of surface electromagnetic waves on photonic band gap materials—$20,450

Middlebury College

Lisa M. Landino: Detection and consequences of peroxynitrite damage to microtubule proteins—$34,736

Northern Arizona University

Paul F. Torrence: 2',5'-phosphodiester-linked oligonucleotides: Synthesis, biophysical and biochemical properties—$23,537

Oberlin College

Manish A. Mehta: Direct measurement of peptide secondary structure in an integrin-peptide complex using solid-state NMR—$43,682

Pacific University

Richard J. Wiener: Control of chaos in Taylor-Couette flow—$36,922

Rose-Hulman Institute of Technology

Karen M. McNally: Novel solid protein solder designs for improved laser-assisted tissue repair—$45,604

Saint Joseph's University

Jean M. Smolen: The role of metal oxide surfaces and naturally occurring organic acids in the chemical reduction of environmental pollutants—$38,800

Saint Louis University

Dana M. Spence: Fundamental studies of air-segmented continuous flow analysis in microbore capillaries—$21,010

San Jose State University

Roger H. Terrill: Preparation and study of novel electroluminescent materials based on mixed-valent lanthanide-ion containing heavy metal fluoride glasses—$37,525

Southeast Missouri State University

Michelle D. Driessen: Effect of spatial confinement on photooxidation reactions performed on zeolite encapsulated TiO_2—$36,000

Jin K. Gong: Enhanced reactivity of carbon dioxide via microwave activation—$42,462

Southwest Texas State University

Linette M. Watkins: Mechanistic investigation of an aromatic desulfinase, 2-(2'-hydroxybiphenyl) benzenesulfinate desulfinase—$28,329

State University of New York College at Geneseo

Wendy Knapp Pogozelski: Fluorescence quantification of deletion events in mitochondrial DNA from Bloom syndrome following oxidative insult—$33,000

Swarthmore College

Andrea L. Stout: Investigation into the effect of strain on the dissociation kinetics of smooth muscle myosin crossbridges—$39,000

Tarleton State University

Daniel K. Marble: High sensitivity detection of hydrogen in wide band gap semiconductors using nuclear reaction analysis—$39,000

Towson University

David M. Schaefer: *Phytophthora infestans* interactions studied by atomic force microscopy—$35,683

Truman State University

Brian D. Lamp: Fabrication and characterization of polyfunctional electrode surfaces on anodized glassy carbon—$31,746

University of Central Florida

Kevin D. Belfield: Nonlinear organic photochemistry—$36,000

University of Colorado at Colorado Springs

Radha Pyati: Polymer solution viscosity effects on reaction dynamics in electrogenerated chemiluminescence—$29,700

University of Colorado at Denver

Robert Damrauer: Solvent effects on acidities and radical reactions: Computational studies from the perspective of a gas phase ion chemist—$35,000

University of Massachusetts, Dartmouth

Jianyi (Jay) Wang: Multiple ionization of light atoms and molecules in interactions with Compton photons—$33,000

University of Minnesota, Duluth

Cecilia Giulivi: Characterization of novel enzymatic activities in proteins exposed to reactive oxygen- and nitrogen-species—$33,998

Paul Kiprof: High-valent early transition metal arene complexes—$34,000

University of North Carolina at Charlotte

Daniel C. Kilper: Quantum optical-pump dynamics in doped-glass lasers—$32,000

Jordan C. Poler: Substrate-directed self-assembly of rigid metallodendrimers—$28,451

Susan R. Trammell: Aspherical structure in young planetary nebulae: An observational study—$28,884

University of North Carolina at Greensboro

Gregory M. Raner: Mechanistic investigation of cytochrome P450 enzymes using covalently modified porphyrin derivatives—$34,552

Thomas P. Shields: A simple biosensor for cancer prognosis based on the recognition of pseudouridine and 1-methyladenosine by in vitro selected RNAs—$40,000

University of North Florida

James L. Garner: Calculations of specific heat and magnetization of III-VI dilute magnetic semiconductor systems—$23,684

University of Northern Iowa

Robert Martin Chin: The preparation and study of transition metal compounds containing bowl shaped hydrocarbon ligands—$36,666

University of Puerto Rico, Rio Piedras Campus

Peter Hofner: Direct imaging of accretion disks around massive protostars—$31,602

University of Saint Thomas

Katherine E. Olson: Investigation of the mechanism of action of the FNR protein—$33,700

University of West Florida

Carl E. Mungan: Solid state laser cooling of organic dyes in modified polymers—$32,528

University of Wisconsin-Eau Claire

Stephen Drucker: Spectroscopic studies of electronically excited states of molecules—$26,700

Marcus T. McEllistrem: Surface chemistry dependence of InGaN alloys on Ga/In surface stoichiometry—$36,575

James A. Phillips: Laboratory investigations of charge-transfer initiated photochemistry in the Earth's atmosphere—$35,500

University of Wisconsin-Superior

Michael A. Waxman: Studying the anisotropy of gas-surface scattering by surface light-induced drift—$29,000

University of the Pacific

Lorraine Cindy Krysac: Attenuating stress waves during the fracture of a brittle material using ferrofluid damping—$34,896

Vassar College

James C. Lombardi: Stellar mergers and blue stragglers in globular clusters—$25,000

Wellesley College

Shane M. Ohline: Studies of molecular orientation at the membrane/air and membrane/solution interface—$32,000

Western Illinois University

Toni Sauncy: Investigation of carrier transfer processes in piezoelectric quantum wells under pressure with photoluminescence excitation spectroscopy—$38,422

Western Kentucky University

Donald W. Slocum: New venues for directed ortho-metalation reactions—$36,000

Whittier College

Howard G. Lukefahr: Nuclear magnetic resonance studies of Fermi liquid and non-Fermi liquid Kondo systems—$33,750

Williams College

Daniel P. Aalberts: Quantum coherent dynamics of photoactive molecules—$37,500

Winthrop University

Patricia J. Bossart-Whitaker: The three-dimensional X-ray structure determination of *Pneumocystis carinii* prohibitin, a putative novel, antiproliferative protein—$34,800

Xavier University of Louisiana

Kathleen V. McCloud: The effects of hydrodynamics on rough surfaces formed by sedimenting particles—$25,304

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COTTRELL SCHOLARS AWARDS

Boston College

Scott J. Miller: Asymmetric catalysis with minimal peptides—$50,000

Columbia University

James L. Leighton: Olefin carbonylation in organic synthesis–an efficient asymmetric synthesis of mycoticin A—$50,000

Georgia Institute of Technology

Rigoberto Hernandez: Stochastic dynamics in irreversible non-equilibrium environments and computer-enhanced communication in the physical chemistry curriculum—$50,000

Michael F. Schatz: Research and teaching in large systems: Control of spatiotemporal chaos in convective flow and improving instruction in introductory courses—$50,000

State University of New York, College of Environmental Science and Forestry

Ivan Gitsov: Self assembling fullerene materials with star-branched and dendritic architecture—$50,000

University of Arkansas, Fayetteville

Matthias C. McIntosh: Total synthesis of eunicellin diterpenes: A new model for the integration of research and teaching missions at research universities—$50,000

University of California, Los Angeles

Benjamin J. Schwartz: Combining femtosecond experiments with quantum computer simulations to build a molecular understanding of charge transfer reactions—$50,000

University of California, San Diego

Dimitri Basov: An infrared probe of interlayer electrodynamics in unconventional superconductors—$50,000

University of Florida

Weihong Tan: Probing single molecules—$50,000

University of Illinois at Urbana-Champaign

David Y. Gin: New methods for glycosylation using activated sulfoxide reagents—$50,000

University of Missouri-Columbia

Sheryl A. Tucker: Starburst dendritic polymers for high performance liquid chromatography: separation of complex chiral and nonchiral heterogeneous mixtures—$50,000

University of New Mexico

Deborah G. Evans: Theoretical studies of electron and exciton transport in dendrimeric macromolecules—$50,000

University of Oklahoma

Ann H. West: X-ray crystallographic analysis of a phosphorylation-regulated molecular switch protein—$50,000

University of Pennsylvania

Chung-Pei Ma: Weighing superclusters with gravitational lensing—$50,000

University of Southern California

Stephen E. Bradforth: Ultrafast electron detachment in the condensed phase—$50,000

University of Toledo

Karen S. Bjorkman: Investigating the nature of circumstellar envelopes throughout the life cycles of stars—$50,000

University of Washington

Gerald T. Seidler: Critical and supercritical complex fluids—$50,000

University of Waterloo

Michel J.P. Gingras: Spatially modulated magnetic moment structures in strongly correlated electron and highly-frustrated quantum antiferromagnetic systems—$50,000

RESEARCH INNOVATION AWARDS

Brigham Young University

Scott D. Bergeson: Ion-electron recombination in an ultra-cold strongly coupled two-component plasma—$34,700

Brown University

Christopher Rose-Petruck: Ultrafast extended X-ray absorption fine structure spectroscopy for measuring molecular dynamics of chemical reactions in solution—$35,000

Clemson University

Steven J. Stuart: Incorporation of electrostatics into reactive potentials for molecular simulation—$34,518

College of William and Mary

Anne C. Reilly: Incorporation of hard carbon thin films with magnetic and giant magnetoresistive systems—$35,000

Colorado School of Mines

Peter W. Sutter: Energy-filtered STM: A novel pathway to high-resolution chemical-contrast imaging—$35,000

Colorado State University

Alan Van Orden: Electronic energy transfer in semiconductor quantum dot bioconjugates: Toward a new class of ultrasensitive optical sensors—$35,000

Duke University

Michael C. Fitzgerald: A new approach for mapping tertiary interactions in protein folding pathways—$35,000

Georgia Institute of Technology

Robert M. Dickson: Direct visualization of antibacterial activity with single molecule microscopy—$35,000

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Louis Andrew Lyon: Microgel bioconjugates: Design, synthesis and application of bioresponsive and biomimetic materials—$35,000

Harvard University

David Ruchien Liu: The development of amplifiable and evolvable unnatural molecules—$35,000

Hongkun Park: Structural phase transition of individual ferroelectric nanocrystals—$35,000

Kansas State University

Brett D. Esry: Microscopic investigation of the collapse of an atomic Bose-Einstein condensate with a negative scattering length—$35,000

Massachusetts Institute of Technology

Jianshu Cao: Eigen-structures of dissipative systems—$35,000

Peter H. Seeberger: Elucidation of the structure-function relationship of heparin—$35,000

Andrei Tokmakoff: Two-dimensional infrared spectroscopy of proteins and peptides—$35,000

Michigan State University

Babak Borhan: Mechanistic studies of β-carotene-15, 15'-dioxygenase. How are retinoids produced?—$35,000

New Mexico State University

Sergei N. Smirnov: Photoinduced electron transfer in oriented double helical DNA—$35,000

Oklahoma State University

Kaladi S. Babu: Novel approach to the fermion mass puzzle and unusual signals in Higgs boson physics—$35,000

Nicholas F. Materer: Atomic emission from neutral species formed by ion bombardment of chemically modified semiconductor surfaces—$33,694

Simon Fraser University

Michael E. Hayden: The study of acoustic phenomena in gases using the techniques of magnetic resonance—$35,000

Igor Herbut: Theory of interacting disordered bosons and the superconductor-insulator transition—$35,000

State University of New York at Buffalo

Thomas Andrew Szyperski: NMR-TROSY detected hydration of DNA in supercooled aqueous systems—$35,000

Texas A&M University

Paul Cremer: The structures and dynamics of phospholipids at the biomembrane/oxide interface—$35,000

Eric E. Simanek: Transient glycosylation with *N*-acetylglucosamine as a mechanism for the control of protein function—$35,000

University of Alberta

Lifang Sun: Hydrophobic-scaffolded artificial receptors for hydrogen-bonding based binding in water and their applications in sensing and separations—$35,000

University of Arizona

Charles A. Stafford: Towards a quantum theory of atomic-scale cohesion and friction in metals—$35,000

University of California, Berkeley

David W. C. MacMillan: Enantioselective transition state recognition: A new strategy for the discovery of asymmetric catalysts through ligand diversity—$35,000

University of California, Los Angeles

Guillaume F. Chanfreau: Investigating the reversibility of the first chemical step of nuclear premessenger RNA splicing—$34,954

Carla M. Koehler: A novel chaperone family in mitochondria that mediates import of membrane proteins: Characterization of the "twin CX_3C motif"—$35,000

University of California, Riverside

Leonard J. Mueller: Inducing nuclear magnetic resonance with an oscillating *electric* field: A novel probe of molecular chirality—$35,000

University of Illinois at Urbana-Champaign

Christopher J. Bardeen: Using shaped pulses to perform four-wave mixing experiments in microscopic sample volumes, with applications to organic electronics—$35,000

University of Maryland

Robert A. Walker: Interfacial width and its effect on transport phenomena: a spectroscopic study of liquid:liquid interfaces using molecular rulers—$35,000

University of Massachusetts, Amherst

Narayanan Menon: Energy storage, dissipation and rigidity in crumpling elastic sheets—$35,000

University of Michigan

Larry W. Beck: Zeolite catalyzed epoxidation mechanism investigated by in situ NMR spectroscopy—$35,000

Cagliyan Kurdak: Search for fractional charge and fractional statistics using single electron transistor amplifiers—$35,000

University of Minnesota

Edgar A. Arriaga: A novel instrument for DNA-analysis in individual mitochondria to determine heteroplasmy within single cells—$35,000

University of Missouri-Kansas City

Zhonghua Peng: Self-assembled rigid polymer networks—$34,800

University of Missouri-Saint Louis

Donald F. Becker: Insights into a novel flavoprotein and redox sensitive gene regulation—$34,500

University of Montana

Thomas S. Rush III: Cooperativity: A new design challenge for de novo proteins—$33,000

University of Montreal

Antonella Badia: Electrochemical modulation of interaction forces in atomic force—$20,986

University of Nebraska-Lincoln

Herman Batelaan: The Kapitza-Dirac effect: a coherent electron wave beamsplitter—$35,000

University of Pennsylvania

Feng Gai: Probing the energy landscape of protein folding—$35,000

University of Vermont

Gregory K. Friestad: Radical addition reactions in asymmetric amine synthesis: Auxiliary and catalyst enantiocontrol—$35,000

University of Washington

Michael V. Romalis: Search for a permanent electric dipole moment in liquid ^{129}Xe—$35,000

University of Wisconsin-Milwaukee

Vladislav V. Yakovlev: New frontiers of microscopic real time imaging of neuronal function—$35,000

Worcester Polytechnic Institute

Germano S. Iannacchione: New approach for practical calorimetric spectroscopy—$35,000

RESEARCH OPPORTUNITY AWARDS

Arizona State University

Robert F. Marzke: Novel approaches to ultra high-temperature NMR studies of liquids—$9,500

Iowa State University

L. Keith Woo: Modified-electrodes for electrocatalytic reduction of halogenated hydrocarbons and carbon dioxide—$25,000

Rutgers University

Spencer Knapp: Photosynthetic special pair models—$25,000

University of Cincinnati

Harry B. Mark, Jr.: Solid phase micro-extraction from aqueous solutions using conducting polymer micro-fiber electrodes: Preconcentration for environmental analyses—$23,550

University of Illinois at Chicago

Timothy A. Keiderling: Protein folding studies with vibrational spectroscopy—$25,000

University of Kansas

Carey K. Johnson: Single-molecule time-resolved investigation of signaling proteins—$25,000

University of Massachusetts, Amherst

Patricia Bianconi: Surface imaging by monolayers and graft polymer layers for nanolithography—$24,799

University of Wisconsin

Stephen F. Nelsen: How does the bridge determine electronic coupling in organic intervalence compounds?—$25,000

GENERAL AWARDS

Coe College

Mario Affatigato and Steven A. Feller: The establishment of a Glassy-Materials Research Laboratory at Coe College—$50,000

Earth Talk

Deborah Byrd: Earth & Sky Radio Series—$35,000

PARTNERS IN SCIENCE AWARDS

(cosponsors listed in parentheses)

City University of New York, City College

Horst Schulz: Fatty acid oxidation in the heart *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Rosa Jimenez, Washington Irving High School*

Mark Steinberg: Transformation-related gene expression in SV40-infected keratinocytes *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Monika Biro, Professional Children's School*

City University of New York, Hunter College

Charles Michael Drain: Self-assembly of photonic materials mediated by disulfide bonds—$14,000 *H. Alexandra Bodha, William H. Maxwell High School*

Richard W. Franck: The anomeric sulfonyl group: The effect of its geometry in a new synthesis of C-glycosides *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Martin Olivieri, Academy of American Studies*

Dixie J. Goss: Determining the specificity of transcription factor interaction with DNA *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Kevin Finnerty, DeWitt Clinton High School*

City University of New York, Queens College

William F. Berkowitz: Synthesis of "skipped dienes" via decarboxylation-Grob fragmentation *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Valentine O. Edobor-Osula, Far Rockaway High School*

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Harry D. Gafney: Excited-state acid-base chemistry: A new quenching mechanism *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Michael J. O'Leary, Benjamin Cardozo High School*

Eastern Washington University

A. Ross Black: An assessment of west slope cutthroat trout habitat in Marshall Creek with special reference to the potential for reintroduction *(The M. J. Murdock Charitable Trust)*—$14,000 *Thomas B. Stralser, Cheney High School*

Evergreen State College

Jeffrey J. Kelly: Molecular microspheres for physiological flow studies *(The M. J. Murdock Charitable Trust)*—$14,000 *Dawn Woodnutt, Capital High School*

Fordham University

Robert H. Beer: Synthesis and characterization of iron salicylaldimine complexes: A possible model compound for iron incorporation into catechol dioxygenase *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Shalton Colquhoun, Wings Academy*

Hofstra University

Rodney B. Finzel: Chemistry of the thermal depolymerization of triglycerides and carbohydrates *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Caren Birchwood-Taylor, Forest Hills High School*

Nanette Wachter-Jurcsak: Investigation of the antioxidant properties of bioflavonoids *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Marietta Cleckley, Uniondale High School*

Lewis and Clark College

Thomas Olson and Herschel B. Snodgrass: Photometric investigations of short-period eclipsing binary star systems *(The M. J. Murdock Charitable Trust)*—$14,000 *Stephen Scannell, Gresham High School*

Oregon Graduate Institute of Science and Technology

David A. Jay: A comparison of suspended particulate trapping in the Columbia and Fraser River estuaries *(The M. J. Murdock Charitable Trust)*—$14,000 *John R. McGinity, Sherwood High School*

Peter Zuber: Molecular genetics of anti-Listerial activity of *Bacillus subtilis* strain 22 *(The M. J. Murdock Charitable Trust)*—$14,000 *Robin J. Hehn, Portland Lutheran High School*

Oregon Health Sciences University

Caroline A. Enns: The effect of the hemochromatosis protein, HFE, on transferrin-mediated iron uptake into cells *(The M. J. Murdock Charitable Trust)*—$14,000 *Neva Lyon, Jefferson High School*

Susan Hayflick: Identifying human genes that cause neurodegeneration *(The M. J. Murdock Charitable Trust)*—$14,000 *Kathleen Mary Sprague, Aloha High School*

Jeffrey Kaye: The contribution of cerebrovascular disease to cognitive decline of the very elderly: A longitudinal MRI study *(The M. J. Murdock Charitable Trust)*—$14,000 *Tim Swihart, Aloha High School*

William R. Woodward: Neurotoxicity in a mouse model of Parkinson's disease *(The M. J. Murdock Charitable Trust)*—$14,000 *David Allan Bruner, Colton High School*

Oregon Regional Primate Research Center

P. Michael Conn: Site-direction mutagenesis of the GnRH receptor *(The M. J. Murdock Charitable Trust)*—$14,000 *Marci Allen, Amity High School*

K.-Y. Francis Pau: Regulation of cholinergic gene expression by estrogens and antiestrogens *(The M. J. Murdock Charitable Trust)*—$14,000 *Rachelle M. Carnes, Century High School*

Henryk F. Urbanski: Neuroendocrine control of gonadotropin-releasing hormone *(The M. J. Murdock Charitable Trust)*—$14,000 *Victor Moore, Tillamook High School*

Oregon State University

George S. Bailey: Gene mutations, cell division, and cell death in experimental cancer *(The M. J. Murdock Charitable Trust)*—$14,000 *Margery S. Barkman, Salem Academy*

Pacific Lutheran University

Jeffery R. Schultz: Antioxidant response to mitochondrial mutations *(The M. J. Murdock Charitable Trust)*—$14,000 *Linda M. Hill, Bothell High School*

Dean A. Waldow: Phase separation kinetics of a three component polymer blend *(The M. J. Murdock Charitable Trust)*—$14,000 *Daryl Gwendolyn Mathews, Governor John R. Rogers High School*

Portland State University

Jonathan J. Abramson: The anion transport protein from skeletal muscle sarcoplasmic reticulum *(The M. J. Murdock Charitable Trust)*—$14,000 *Guy R. Duncan, McKay High School*

Dean B. Atkinson: Enhanced hydrocarbon emissions from pine trees to ozone pollution: Correlation, biological mechanism and implications for the Portland, Oregon airshed *(The M. J. Murdock Charitable Trust)*—$14,000 *Janet Nees, Sunset High School*

Gary L. Gard: Conducting and superconducting charge transfer salts *(The M. J. Murdock Charitable Trust)*—$14,000 *Dennis Sosnovske, Corbett High School*

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Richard Forbes: Population biology of western painted turtle and northwestern pond turtle in northwestern Oregon *(The M. J. Murdock Charitable Trust)*—$14,000 *George Cashdollar, Oregon City High School*

Bryant A. Gilbert: Oxidation chemistry of nitric oxide: Experimental and ab initio molecular orbital calculation investigations *(The M. J. Murdock Charitable Trust)*—$14,000 *Thomas Stueve, Jefferson High School*

Stevens Institute of Technology

Ajay K. Bose: Biosynthesis of barley alkaloids *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Eric F. Paul, Northern Highlands Regional High School*

Carol L. Stone: The kinetics of retinoid metabolism by human fetal liver alcohol dehydrogenase *(The Camille and Henry Dreyfus Foundation)*—$14,000 *Kelly Iwaki, Thurgood Marshall Academy*

University of Idaho

Thomas E. Bitterwolf: Matrix, solution and supercritical fluid photolysis of transition metal nitrosyl compounds *(The M. J. Murdock Charitable Trust)*—$14,000 *Shelly Potter, Lewiston Senior High School*

University of Montana

George D. Stanley: Recoveries from mass extinction *(The M. J. Murdock Charitable Trust)*—$14,000 *Thomas Jon Andres, Saint Labre Indian School*

University of Washington

Carol H. Sibley: Analysis of mutations to drug resistance in malaria parasites *(The M. J. Murdock Charitable Trust)*—$14,000 *Peggy O'Neill Skinner, The Bush School*

PARTNERS SUPPLEMENTAL AWARDS

Canby High School, Canby, Ore.

Coleen Swihart: Exploring issues in environmental science through research-based investigations *(The M. J. Murdock Charitable Trust)*—$3,000

Capital High School, Olympia, Wash.

Judith K. Henry: A fast, functional spectroscopy lab for high school level investigations *(The M. J. Murdock Charitable Trust)*—$3,000

Catlin Gabel School, Portland, Ore.

Lynda W. Jones: Analysis of myoglobin using UV/VIS spectrophotometry *(The M. J. Murdock Charitable Trust)*—$3,000

Eagle High School, Eagle, Idaho

Robert Eugene Beckwith: Determination of irrigation returns impacts on the Boise River with remediation models *(The M. J. Murdock Charitable Trust)*—$3,000

Gold Beach High School, Gold Beach, Ore.

Joel M. Kuper: Partnerships in biotechnology research–fish genetics: Analysis of genetic variance in sea-run and residential cutthroat trout *(The M. J. Murdock Charitable Trust)*—$3,000

Great Falls High School, Great Falls, Mont.

Joseph Barlow: Investigation of antibiotic and anti-HIV compounds from the marine bacterium *Alteromonas* sp. *(The M. J. Murdock Charitable Trust)*—$1,398

Juanita High School, Kirkland, Wash.

Jeanne Ting Chowning: Advanced research topics in biotechnology at Juanita High School—$3,000

Lake City High School, Coeur D'Alene, Idaho

Scott A. Jacobson: I/O, It's off to work I go! *(The M. J. Murdock Charitable Trust)*—$3,000

North Medford High School, Medford, Ore.

Mark Geisslinger: Biotechnology lab activities for high school students *(The M. J. Murdock Charitable Trust)*—$3,000

Nyssa High School, Nyssa, Ore.

Ken Dickey: Fractal dimension-A new measurement tool for integrated science research in physics *(The M. J. Murdock Charitable Trust)*—$1,100

Dean R. Marsh: Bringing biotechnology lab activities to Nyssa High School *(The M. J. Murdock Charitable Trust)*—$1,595

Wilsonville High School, Wilsonville, Ore.

Holly R. Chidsey-Gardner: Restriction analysis and in-situ hybridization in advanced genetics *(The M. J. Murdock Charitable Trust)*—$3,000

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INDEPENDENT AUDITORS' REPORT

Board of Directors
Research Corporation
Tucson, Arizona

We have audited the accompanying statements of financial position of Research Corporation (the "Foundation") as of December 31, 1999 and 1998, and the related statements of activity and changes in net assets and of cash flows for the years then ended. These financial statements are the responsibility of the Foundation's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, such financial statements present fairly, in all material respects, the financial position of the Foundation at December 31, 1999 and 1998, and the results of its operations and its cash flows for the years then ended in conformity with accounting principles generally accepted in the United States of America.

DELOITTE & TOUCHE LLP
April 14, 2000

Statements of Financial Position
December 31, 1999 and 1998

ASSETS	1999	1998
CASH AND CASH EQUIVALENTS	$ 156,007	$ 6,743,004
ACCRUED DIVIDENDS AND INTEREST RECEIVABLE (Note 6)	109,369	88,642
MARKETABLE SECURITIES – At Market (Note 2)	129,156,020	89,202,679
PROGRAM-RELATED INVESTMENT IN RESEARCH CORPORATION TECHNOLOGIES, INC. (Note 3)	25,000,000	25,000,000
SCIENCE AND TECHNOLOGY INVESTMENTS (Notes 4 and 10)	5,676,382	7,456,670
OTHER INVESTMENTS (Note 5)	7,963,305	5,049,757
NOTES RECEIVABLE:		
Note receivable (Note 6)	150,000	274,226
Real estate loan note receivable (Note 7)	290,000	290,000
Total notes receivable	440,000	564,226
PROPERTY AND EQUIPMENT:		
Tenant improvements	358,289	353,673
Furniture, fixtures and equipment	305,983	291,696
Total property and equipment	664,272	645,369
Less accumulated depreciation	(582,712)	(553,338)
Property and equipment – net	81,560	92,031
PREPAID PENSION COST (Note 9)	3,497,266	2,973,377
OTHER ASSETS (Note 10)	1,080,579	28,697
TOTAL	$173,160,488	$137,199,083
LIABILITIES AND NET ASSETS		
LIABILITIES:		
Grants payable	$ 4,334,704	$ 4,632,659
Line of credit (Note 8)	2,025,047	
Other (Note 9)	643,703	532,698
Total liabilities	7,003,454	5,165,357
NET ASSETS – Unrestricted	166,157,034	132,033,726
TOTAL	$173,160,488	$137,199,083

See notes to financial statements.

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Statements of Activity and Changes in Net Assets
Years Ended December 31, 1999 and 1998

	1999	1998
REVENUE:		
Unrestricted revenues and gains:		
Interest and dividends from marketable securities	$ 1,812,532	$ 1,513,173
Interest income from program-related investment (Note 3)	1,750,000	1,750,000
Interest income from notes receivable (Notes 6 and 7)	27,551	126,919
Pension income (Note 9)	523,889	468,696
Total unrestricted revenues and gains	4,113,972	3,858,788
Contributions released from restrictions	447,498	438,138
Total revenue	4,561,470	4,296,926
EXPENSES (Note 12):		
Grants approved	8,550,196	5,501,736
Science advancement	1,142,922	1,053,889
Information and communications	218,644	219,489
General and administrative expenses	1,255,011	1,245,571
Postretirement expense (Note 9)	131,561	120,219
Interest and other expense	139,069	204,018
Total expenses	11,437,403	8,344,922
AMOUNT OF REVENUE UNDER EXPENSES BEFORE SECURITIES TRANSACTIONS	(6,875,933)	(4,047,996)
NET GAIN ON INVESTMENTS (Note 2)	40,999,241	15,037,147
EXCESS FOR THE YEAR	34,123,308	10,989,151
NET ASSETS, BEGINNING OF YEAR	132,033,726	121,044,575
NET ASSETS, END OF YEAR	$166,157,034	$132,033,726

See notes to financial statements.

Statements of Cash Flows
Years Ended December 31, 1999 and 1998

	1999	1998
CASH FLOWS FROM OPERATING ACTIVITIES:		
Interest and dividends received	$ 1,791,805	$ 1,537,184
Interest received from program-related investment	1,750,000	1,750,000
Interest received from notes receivable	27,551	126,919
Contributions received	447,498	438,138
Grants paid	(6,232,985)	(4,091,453)
Other income		3,754
Cash paid to suppliers and employees	(2,528,379)	(2,726,339)
Interest paid	(90,561)	(207,772)
Net cash used in operating activities	(4,835,071)	(3,169,569)
CASH FLOWS FROM INVESTING ACTIVITIES:		
Purchase of marketable securities	(19,585,516)	(24,660,919)
Proceeds from sales of marketable securities	19,668,111	47,068,264
Purchase of science and technology investments	(2,297,547)	(3,298,000)
Purchase of other investments	(2,000,000)	(5,000,000)
Proceeds from sale of other investments	400,000	
Repayments on note receivable	56,882	52,768
Purchases of property and equipment	(18,903)	(49,854)
Net cash (used in) provided by investing activities	(3,776,973)	14,112,259
CASH FLOWS FROM FINANCING ACTIVITIES –		
Net borrowings on line of credit	2,025,047	(4,202,845)
NET (DECREASE) INCREASE IN CASH AND CASH EQUIVALENTS	(6,586,997)	6,739,845
CASH AND CASH EQUIVALENTS, BEGINNING OF YEAR	6,743,004	3,159
CASH AND CASH EQUIVALENTS, END OF YEAR	$ 156,007	$ 6,743,004
RECONCILIATION OF EXCESS FOR THE YEAR TO NET CASH USED IN OPERATING ACTIVITIES:		
Excess for the year	$ 34,123,308	$ 10,989,151
Adjustments to reconcile excess for the year to net cash used in operating activities:		
Net realized gains on sales of investments	(16,286,106)	(11,356,586)
Unrealized net depreciation of investments	(24,713,137)	(3,680,561)
Write-down of note receivable	67,344	
Noncash grants	2,615,165	
Depreciation and amortization	29,374	50,645
(Decrease) increase in accrued dividends and interest receivable	(20,727)	24,011
Increase in prepaid pension costs	(523,889)	(468,696)
Decrease in other assets	10,788	32,833
(Decrease) increase in grants payable	(297,955)	1,410,283
Increase in postretirement liability	131,561	120,219
Increase (decrease) in accounts payable	29,203	(290,868)
NET CASH USED IN OPERATING ACTIVITIES	$(4,835,071)	$(3,169,569)

See notes to financial statements.

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NOTES TO FINANCIAL STATEMENTS
YEARS ENDED DECEMBER 31, 1999 AND 1998

1. SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

Nature of Business – Research Corporation (the "Foundation") is a New York not-for-profit corporation dedicated to the advancement of science.

Basis of Accounting – The financial statements are prepared on the accrual basis of accounting and are prepared in accordance with standards set forth in the Statement of Financial Accounting Standards ("SFAS") No. 117, *Financial Statements of Not-for-Profit Organizations*, and the American Institute of Certified Public Accountants' *Audit and Accounting Guide for Audits of Not-for-Profit Organizations*.

Securities Valuation – The Foundation carries its investments in marketable securities at fair market value (Note 2). Realized gains and losses are computed based on the difference between the net proceeds received and cost at time of acquisition using the first-in, first-out ("FIFO") method. Unrealized net appreciation or depreciation of investments in marketable securities represents the change in the difference between acquisition cost and current market value at the beginning of the year versus the end of the year.

Other Investments consisting of unconsolidated limited partnership and equity securities without a readily determinable fair value are recorded at the lower of aggregate cost or market. The cost of investments sold is determined using the specific identification method. Permanent impairments are recognized in the period in which they occur.

Revenue and Expenses – Interest income is recorded as earned; dividends are accrued as of the ex-dividend date. Grant expense is recorded at the time of approval by the Board of Directors.

Contributions – Restrictions on contributions received are satisfied in the year the contributions are received. Contributions are expended in the year received.

Property and Equipment are stated at cost. Depreciation is calculated using the straight-line method over estimated useful lives as follows:

Tenant improvements	5 years
Furniture, fixtures and equipment	5 – 10 years

Maintenance and repairs are charged to operations as incurred. Major renewals and betterments are capitalized.

Income Taxes – The Foundation qualifies as a tax-exempt private operating foundation under Internal Revenue Code Section 4940(d).

Statement of Cash Flows – For purposes of reporting cash flows, cash and cash equivalents include cash on hand, demand deposits, savings accounts and highly-liquid debt instruments purchased with an original maturity of three months or less which are not carried in the Foundation's portfolio of marketable securities.

New Accounting Pronouncements – In June 1998, the Financial Accounting Standards Board ("FASB") issued SFAS No. 133, *Accounting for Derivative Financial Instruments and Hedging Activities.* SFAS No. 133, as amended, becomes effective for the Foundation January 1, 2001 and requires that entities record all derivatives as assets or liabilities, measured at fair value, with the change in fair value recognized in earnings or in comprehensive income, depending on the use of the derivative and whether it qualifies for hedge accounting. The Foundation is evaluating the impact, if any, that will result from the adoption of this standard.

Use of Estimates – The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting periods. Actual results could differ from those estimates.

Reclassifications – Certain reclassifications have been made to the 1998 financial statements to conform to the 1999 presentation.

2. MARKETABLE SECURITIES

Marketable securities at December 31 consisted of the following:

	1999		1998	
	Market Value	Cost	Market Value	Cost
Capital Guardian Trust Mutual Funds:				
Emerging Markets Growth Fund	$ 4,853,696	$ 4,157,495	$ 2,770,515	$ 4,157,495
Global Equity Fund	119,211,970	70,765,187	86,432,164	59,861,677
American High Income Fund	5,090,354	5,300,000		
Total	$129,156,020	$80,222,682	$89,202,679	$ 64,019,172

The objectives of the mutual funds are as follows:

a. *Emerging Markets Growth Fund* seeks to obtain long-term growth of capital through investment in equity securities of businesses located in developing countries.

b. *Global Equity Fund* seeks to achieve capital growth and future income through investments in a portfolio of securities of U.S. issuers, American depository receipts for securities of foreign issuers, and securities whose principal markets are outside of the United States.

c. *American High Income Fund* seeks to achieve monthly income through investments primarily in bonds and also U.S. and foreign securities

Net gain on investments consists of the following for the years ended December 31:

	1999	1998
Net realized gain	$16,286,104	$ 11,356,586
Unrealized net appreciation on investments	24,713,137	3,680,561
Net gain on investments	$40,999,241	$ 15,037,147

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3. PROGRAM-RELATED INVESTMENT IN RESEARCH CORPORATION TECHNOLOGIES, INC.

On March 2, 1987, as amended on March 25, 1994, in accordance with Section 1605(c) of the Tax Reform Act of 1986, the Foundation and Research Corporation Technologies, Inc. ("RCT"), a nonprofit corporation subject to regular corporate income tax laws, entered into agreements through which RCT assumed responsibility for the Technology Transfer Program (the "Program") which the Foundation had operated for many years. In addition to the transfer of the Program, the Foundation transferred $35,000,000 in cash and securities in exchange for a $35,000,000 fully subordinated unsecured note from RCT (the "Note") due February 28, 2017.

RCT has prepaid $10,000,000 of the Note, and the remaining $25,000,000 principal amount of the amended note is due on February 28, 2017, subject to acceleration at the option of the Foundation after December 31, 2012 provided RCT's retained earnings exceed $100,000,000. Basic interest at the rate of 7 percent per annum on the outstanding principal amount is due semiannually.

To qualify as a program-related investment under Section 4944(c) of the Tax Reform Act of 1986, the terms of the loan were required to be less than prevailing terms. In addition, this investment is a vehicle for the Foundation to continue one of its charter purposes. As there are no comparable alternative program-related investments available to the Foundation, the Foundation believes it is not practicable to estimate the fair value of this investment.

Interest income on the Note for each of the years ended December 31, 1999 and 1998 was $1,750,000.

4. SCIENCE AND TECHNOLOGY INVESTMENTS

The Foundation has ownership interests in various entities that engage in the advancement of science and technology. Such investments are not readily marketable and are carried at cost. At December 31, such investments consisted of the following:

	1999	1998
Large Binocular Telescope Project (Note 10)	$4,226,382	$6,156,670
Seaphire International Inc. (formerly Planetary Design Corporation)	1,150,000	1,000,000
Magellan University	300,000	300,000
Total science and technology investments	$5,676,382	$7,456,670

5. OTHER INVESTMENTS

Other investments at December 31 consisted of the following:

	1999	1998
Limited partnership interest (AG Super Fund LP)	$5,915,276	$5,000,000
Limited partnership interest (AG Realty Fund IV LP)	2,048,029	
Other		49,757
Total other investments	$7,963,305	$5,049,757

At December 31, 1999 and 1998, other investments are estimated to be recorded at fair value.

The objective of AG Super Fund LP is to achieve capital appreciation though specialized investment strategies, including investing in merger arbitrage, distressed debt, special situations and convertible hedging. The fair value of other investments is estimated based on the most recent arms-length sale of equity interests by the enterprise of other investors.

The objective of AG Realty Fund IV LP is to invest in real estate assets, including options and mortgage loans.

6. NOTE RECEIVABLE

The Foundation has a note receivable with an original balance in the amount of $530,000 which is to be paid in monthly installments of principal and interest of $6,300 over ten years with the balance due at maturity in March 2003. The promissory note is collateralized by a first Deed of Trust on the Foundation's former property consisting of land, building and improvements and bears interest at the annual rate of 7.53 percent. During 1999, the Foundation forgave $67,344 on the note, leaving a balance of $150,000. Subsequent to December 31, 1999, the remaining balance on the note was paid in full. Interest income on the note was $18,718 and $22,832 for the years ended December 31, 1999 and 1998, respectively.

7. REAL ESTATE LOANS

In February 1996, the Foundation entered into an agreement to loan $1,040,000 to a limited liability company for the purchase of a property. The loan bears interest at 10 percent per annum, payable in monthly interest only with principal due on March 1, 2006, and is collateralized by a collateral assignment and security agreement on the acquired property. In addition to the above stated annual interest, the Foundation has a contingent interest equal to 50 percent of the gain (as defined) on sale of the property, if any. At December 31, 1999 and 1998, the $1,040,000 of principal was outstanding on this loan. Based upon the property's recent declining operational results, the Foundation has established a specific reserve of $750,000 against the principal balance, and has ceased recognition of interest income not paid. The Foundation recognized interest income of $8,833 and $104,000 for the fiscal years ended December 31, 1999 and 1998, respectively. Accrued interest receivable related to this loan was $8,333 at December 31, 1998.

8. LINE OF CREDIT

The Foundation has a $4,000,000 revolving line of credit which is due August 4, 2000 and bears interest at the prime rate (8.5% at December 31, 1999). At December 31, 1999, $2,025,047 was outstanding and no amount was outstanding on the line at December 31, 1998. The Foundation recognized interest expense of $90,561 and $207,722 for the years ended December 31, 1999 and 1998, respectively. Accrued interest payable related to the line of credit was $20,239 at December 31, 1999.

9. PENSION PLAN AND POSTRETIREMENT BENEFITS

Pension Plan – The Foundation has a noncontributory defined benefit pension plan (the "Plan"), covering substantially all of its employees. The benefits provided by the Plan are generally based on years of service and employees' salary history. It is the Foundation's policy to fund pension cost accrued. At December 31, 1999, the Plan is in an overfunded status and no contributions are required.

The components of the net periodic pension income for the years ended December 31 are as follows:

	1999	1998
Service cost – benefits earned during the period	$ 210,592	$ 149,919
Interest cost on projected benefit obligations	164,024	148,896
Expected return on Plan assets	(681,656)	(591,119)
Net amortization and deferral	(263,568)	(220,208)
Net periodic pension income	(570,608)	(512,512)
Postretirement benefits transfer	46,719	43,816
Total pension income	$ (523,889)	$ (468,696)

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Assumptions used in the accounting for the years ended December 31 were:

	1999	1998
Discount rate	7.75%	6.75%
Rate of increase in compensation levels	5.75%	5.00%
Expected long term rate of return on assets	7.50%	7.50%

The measurement date for the Plan is December 31. The following sets forth the Plan's funded status at December 31:

	1999	1998
Actuarial present value of benefit obligations:		
Accumulated benefit obligation including vested benefits of $2,169,944 and $2,121,083, respectively	$ 2,211,157	$ 2,155,634
Projected benefit obligation	$(2,516,561)	$(2,421,032)
Plan assets at fair value, primarily invested in stocks and bonds	10,591,177	9,156,472
Funded status	8,074,616	6,735,440
Unrecognized transition net asset	(567,949)	(681,539)
Unrecognized net gain	(4,104,581)	(3,186,978)
Unrecognized prior service cost	95,180	106,454
Prepaid pension cost	$ 3,497.266	$ 2,973,377

During 1999 and 1998, $46,719 and $43,816, respectively, was transferred out of the Plan to provide for payment of postretirement medical benefits. This transfer was made in accordance with the Omnibus Budget and Reconciliation Act and was treated as a negative contribution in the current year. In addition, during each of the years 1999 and 1998, total benefits paid were $121,914 and $121,194. There were no other participant or employer contributions in either 1999 or 1998.

Postretirement Plan – In addition to providing pension benefits, the Foundation provides certain health care benefits to retired employees and their spouses. Substantially all of the Foundation's employees may become eligible for these benefits if they reach normal retirement age while working for the Foundation.

Effective January 1, 1996, the Foundation adopted SFAS No. 106, *Employers' Accounting for Postretirement Benefits Other Than Pensions* on a prospective basis. The net transition obligation represents the difference between the Foundation's January 1, 1996 accrued postretirement benefit costs prior to the adoption of SFAS No. 106 and the Plan's unfunded liability as of that date. The net transition liability at January 1, 1996 was $1,516,244 and will be amortized over 20 years.

The components of net periodic postretirement benefit cost at December 31 are as follows:

	1999	1998
Service cost – benefits earned during the period	$ 40,412	$ 33,505
Interest cost on accumulated postretirement benefit obligation	84,548	86,411
Net amortization and other	47,979	44,119
Net periodic postretirement benefit cost	172,939	164,035
Pension plan transfer	(41,378)	(43,816)
Total	$131,561	$120,219

During 1999 and 1998, benefits paid were $41,378 and $51,883, respectively. Other than the transfer from the Pension Plan (Note 8), there were no participant or employer contributions.

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A reconciliation of the accumulated postretirement benefit obligation to the liability recognized in the consolidated balance sheet is as follows at December 31:

	1999	1998
Accumulated benefit obligation	$1,271,880	$1,380,588
Unrecognized net gain subsequent to transition	494,158	329,701
Unrecognized transition obligation	(1,212,993)	(1,288,805)
Accrued postretirement benefit liability	$ 553,045	$ 421,484

The actuarial calculation assumes a health care inflation assumption of 8 percent in 1999 and grades down uniformly to 4 percent after eight years and remains level thereafter. The health care cost trend rate has an effect on the amounts reported. Increasing the health care inflation rate by 1 percent would increase the December 31, 1999 accumulated postretirement benefit obligation by $125,367 and the 1999 net periodic postretirement benefit cost by $32,782. The discount rates used in determining the accumulated postretirement benefit obligation and net periodic postretirement benefit cost was 6.75 percent. The Foundation's postretirement medical plans are not funded. Prior to 1996, the cost of providing postretirement benefits was expensed as incurred.

10. COMMITMENT

The Foundation agreed to commit up to $7,500,000 plus 12.5 percent of the operating expenses for each year to the Large Binocular Telescope Project (the "Project") which was organized to construct a telescope. In return for the commitment, the Foundation receives observing time for use or sale to other astronomy research institutions. As of December 31, 1999 and 1998, $8,304,217 and $6,156,670, respectively, had been funded to the Project under the commitment by the Foundation and is recorded in Science and Technology Investments.

In 1999, the Foundation sold one quarter of its viewing rights to a research institution in exchange for $400,000 cash and a note receivable of $1,062,669 (net of unamortized discount of $137,331 based on an imputed interest rate of 8.5 percent).

In addition, the Foundation granted viewing rights for additional nights to a research institution. Grant expense of $2,615,167 was recognized in relation to these transfers of viewing rights to research institutions.

11. LITIGATION

The Foundation is subject to a claim arising out of the conduct of its business. Management believes the matter is without merit and intends to contest it vigorously. This claim when finally concluded, in the opinion of management, based on information it presently possesses, will not have a material adverse effect on the Foundation's financial position, results of operations, or cash flows.

12. RELATED PARTY TRANSACTIONS

The Foundation and RCT have certain agreements under which:

a. In February 1993, the Foundation entered into an office facilities lease agreement with RCT which had an expiration date of December 31, 1998. In April 1998, this lease agreement was amended to include an additional suite, effective August 1, 1998, and to amend the expiration date to July 31, 2003. Lease expense paid to RCT under this agreement for the years ended December 31, 1999 and 1998 was approximately $175,900 and $123,500, respectively.

b. The Foundation pays a management service fee to RCT for making available professional and other services to the Foundation to the extent that such services are reasonably required by the Foundation. The fee for such services is negotiated yearly and is approved in the budget by the Foundation's Board of Directors. The management service fee for the years ended December 31, 1999 and 1998 was approximately $102,000 and $98,100, respectively.

c. At December 31, 1999 and 1998, the Foundation had an amount payable to RCT of approximately $44,000 and $77,000, respectively, relating to expenses paid by RCT on behalf of the Foundation.

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